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DEPARTMENT OF COMMERCE
BUREAU OF STANDARDS
WASHINGTON

Letter
Circular
LC 310

(October 19,1931)

SPECIFICATIONS, STANDARDIZATION, AND USE OF STEEL TAPES

1. Certificates and Reports. Tapes conforming to the specifications given below will be certified by the Bureau of Standards and a precision seal showing year of test will be placed on each tape. For tapes not conforming to the specifications a report will be issued but the tape will not be sealed. The Bureau's serial number on a tape simply signifies that it has been tested by the Bureau and either a certificate or a report issued. The lengths of steel tapes will be given to the nearest 0.001 foot or 0.1 mm and the temperature of comparison will be stated to the nearest degree.

2. Specifications for Standard Steel Tapes. A steel tape is standard when it conforms to the following specifications: It shall be made of a single piece of metal ribbon, and none of the graduations shall be on pieces of solder or on sleeves attached to the tape or on wire loops, spring balances, tension handles, or other attachments liable to be detached or changed in shape. The error in the total length of the tape, when supported horizontally throughout its length at the standard temperature of 68°F. (20°C.) and at standard tension, shall not be more than 0.1 inch per 100 feet (2 millimeters per 25 meters). The standard tension is 10 pounds (4.5 kilograms) for tapes 25 to 100 feet or from 10 to 30 meters in length and 20 pounds (9 kilograms) for tapes longer than 100 feet or 30 meters.

3. Standard Tension. See Specifications in Section 2.

4. Standard Temperature. See Specifications in Section 2. The comparisons of a tape with the United States Bench Standard are usually made at a temperature higher than 68° Fahrenheit (20° Centigrade) and in reducing to standard temperature (or any other temperature) the coefficient of expansion of the tape is assumed to be 0.00000645 per degree Fahrenheit (0.0000116 per degree Centigrade). This coefficient may be considered as correct for all except the most precise geodetic tapes in which case the use of steel tapes is not recommended. Determinations of the coefficients of expansion of both ordinary steel tapes and stainless steel tapes give the value stated above within the limits of all ordinary measurements ever made with these tapes.

5. Comparison of Tapes with the Standards.

(a) Unless otherwise stated, the comparisons of tapes with the Bench Standard are made at the center of the lines on the edge to which the shortest graduations are ruled. If all the graduations extend entirely across the tape, the ends of the graduation lines away from the observer when the zero of the tape is at his left hand are used.

(b) On tapes which have been cut off at the zero mark, the extreme end of the steel ribbon is taken as the zero point and not the center of any line that may be at that point.

(c) On tapes which have the zero point on a loop attached to the steel ribbon at the end, the zero is taken at the outside of this loop unless noted to the contrary. Attention is called to the fact that tapes of this character are not standard tapes and will not be certified. (See Section 2).

(d) A description of the equipment and methods used at the Bureau of Standards in the testing of tapes is given in Circular 328 entitled, "Testing of Measuring Tapes at the Bureau of Standards", a copy of which may be procured from the Superintendent of Documents, Government Printing Office, Washington, D. C., at 10 cents per copy.

(e) The Bureau's Fee Schedules 214 for testing steel tapes, and 215 for testing invar tapes may be obtained, without charge, on application to the Bureau of Standards.

6. Young's Modulus of Elasticity. In a research on some physical characteristics of steel tapes, Mr. C. D. Shepard, of the Bureau of Standards, found Young's Modulus of Elasticity of a group of steel tapes to be as follows:

Number of Tapes	Dimensions of Tapes	Description	Young's Modulus of Elasticity (Pounds per square inch)
12	1/4" by 0.006" to 1/4" by 0.016"	Black finish	28.0×10^6
10	3/32" by 0.019" to 1/4" by 0.017"	Black finish	27.6×10^6
17	5/16" by 0.016" and variations	Graduations on solder or babbitt metal	28.5×10^6

Variations in the material in the different tapes cause an uncertainty of two or three units in the third significant figure in the mean values in the above table.

A tape having the customary black finish has a smaller modulus of elasticity than has the original steel ribbon from which it is made, because there is included in the cross-sectional area of the finished tape not only the steel but also the protective coating which has a lower modulus. A value 28.0×10^6 pounds per square inch may for all practical purposes be assumed for any steel tape, because the maximum error introduced by this assumption in using a 200-foot tape with a change in tension of 15 pounds would be about 0.001 foot.

7. Correction for Sag. The difference in the length of a tape when supported throughout and when supported at equidistant points at the same height, the tension remaining constant, is equal to

$$\frac{L}{24}\left(\frac{w\,d}{P}\right)^2$$

where L is the length of the tape, w is the weight of the tape per unit length, d the distance between points of support, and P the tension on the tape. These must be in consistent units; usually L and d in feet, w in pounds per foot, and P in pounds.

In the research cited above it was found that, for the 45 tapes tested, using tensions between 10 and 25 pounds, the difference between the observed value and that obtained from the formula for the correction for sag did not exceed 0.001 foot when the interval between the supports was 25 or 50 feet.

Furthermore, when supported at the 0 and 100-foot points at 10 pounds tension, the difference between the observed value and the computed value for the correction for sag did not exceed 0.002 foot, provided the correction for sag was not larger than 0.060 foot. When the tension was increased to 15, 20, or 25 pounds, under the same conditions of support, the difference between the observed values and the computed value for the correction for sag, with the exception of a few tapes, did not exceed 0.001 foot. Moreover, there may be an agreement between the observed value and the computed value to 0.001 foot for individual tapes of relatively heavy weight when at a tension less than 15 pounds.

The formula was shown to be applicable to 100-foot tapes of non-uniform density, provided sufficient tension is used, e.g., 15 pounds or more.

8. Tension of Accuracy. If the length of a tape is known when supported throughout its length at standard tension and standard temperature, this information, together with a knowledge of certain constants concerning the physical properties of the tapes will enable one to determine the tension to apply to the tape when supported at equidistant points at any known temperature to obtain the nominal length. These constants should be accurately determined. The case in which the observed temperature is the same as the standard temperature is given in text books on surveying, and the tension to be used in this case is often termed the normal tension. It is found by equating the correction for tension to the correction for sag. The general case is an extension of this specified case. The equation is:

$$P_1^3 - \left[P_o - AE \propto (t_1 - t_o)\right] P_1^2 - \frac{AE\, w^2 d^2}{24} = 0$$

where P_1 = tension to be applied to the tape, when used at the observed temperature t_1 and supported at equidistant points at a distance d apart, in order that the tape will have its nominal length.

P_o = tension at which tape has its nominal length when supported throughout at standard temperature, t_o.

A = cross-sectional area of the tape.

E = Young's modulus of elasticity.

$\propto$ = coefficient of thermal expansion.

t_1 = observed temperature.

t_o = standard temperature.

w = weight of the tape per unit length.

d = distance between the equidistant points of support.

The computation may be carried out rapidly by graphical methods and thus is suitable for use in the field. Details of this method will be furnished on application to the Bureau of Standards.

It may also be convenient to plot curves for individual tapes showing tension of accuracy as a function of temperature. The tension of accuracy of a tape supported throughout when plotted against temperature gives a straight line.

9. Precautions in the Use of Tapes. In the case of tapes for precision work, attention should be paid to the temperature and to the tension and corrections made for variation from the condition given in the certificate or report. The accuracy of the balance used with the tape should be checked by comparison with a calibrated balance or by the use of calibrated weights used with a pulley so that the balance is horizontal.

10. Submitting Tapes to the Bureau of Standards. Tapes for test by the Bureau of Standards, should be shipped, with transportation charges prepaid, marked "Bureau of Standards, Attention of Division II-1, Washington, D.C." A letter should be sent to the Bureau requesting the test, stating exactly what tests are desired.